This nonprovisional application claims priority under 35 U.S.C. § 119(a) on Patent Application No(s). 2003-035594 filed in Japan on February 13, 2003, the entire contents of which are hereby incorporated by reference.

Method of Designing Golf Club

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a method of designing a golf club by utilizing a computer. More particularly, the present invention is intended to efficiently design a wood head of the golf club having a sufficient strength and excellent restitution characteristics. To do so, by using a wood head model of the golf club and a golf ball model composed of a plurality of finite elements, stresses generated when the ball model is hit at different hitting positions of the face part of the head model are computed. Based on the computed values of the stresses, the thickness of a thin metal plate to be mounted on the face part of the head model is controlled to make the stress generated at the different hitting positions uniform.

Description of the Related Art

A metal plate is disposed on the face of a wood head of a conventional golf club. To improve the restitution

characteristic of the wood head at the time when it hits a golf ball, it is effective to thin the metal plate disposed on the face to approximate the natural frequency of the face part to that of the golf ball, based on an impedance matching theory. Therefore the metal plate is thinned in recent years.

However, the thin metal plate causes the strength of the wood head to be low. That is, to improve the restitution characteristic of the wood head and to increase the strength thereof are contrary to each other. It is desirable to design the wood head so that it has a degree of strength demanded by a user and highest restitution performance. The conventional procedure of determining the thickness of the metal plate constituting the face of the wood head depends greatly on experience and perception and requires immense trial-and-error investigations. Thus it takes much time to design the wood head and there may be a variation in the guiding principle in designing the wood head. Therefore various proposals for efficiently designing the wood head superior in the restitution performance have been made.

For example, as disclosed in Japanese Patent Application Laid-Open No. 9-149954, the present applicant proposed the following method serviceable for designing the golf club head: Initially, the three-dimensional configuration of the golf club head is measured by a three-dimensional configuration measuring apparatus. Based on the data of measured three-

dimensional configuration, a finite element method (FEM) model is formed by using a construction-analyzing pre-program. Thereafter by using an analyzing software commercially available, the inertial main shaft of the FEM model and its main inertial moment are computed. The analyzing software allows computations of a stress and the like at a ball-hitting time and computations of the inertial main shaft and the main inertial moment in the initial configuration of the golf club head.

As disclosed in Japanese Patent Application Laid-Open No. 9-168613, a golf club head having a hollow construction is proposed. The golf club head has a hitting portion disposed at the predetermined region in the center of the face part. The hitting portion is strong enough to withstand an impact applied thereto. A portion having a spring constant smaller than that of the hitting portion is formed on the periphery of the hitting portion in the face part.

However, in the method disclosed in Japanese Patent Application Laid-Open No. 9-149954, the inertial main shaft and the main inertial moment in the initial configuration of the golf club head are computed, which is serviceable for designing the golf club head. However, the method has room for improvement in designing the golf club head so that it has superior restitution characteristics and a high strength.

In the golf club head disclosed in Japanese Patent

Application Laid-Open No. 9-168613, it is difficult to provide the golf club head with superior restitution characteristics and a high strength by only forming the portion having a small spring constant in the face part. Further it is very difficult to determine where the portion having the small spring constant should be disposed. Consequently it is necessary to make various types of face parts on an experimental basis and evaluate the produced face parts repeatedly. Thus much time and labor are required in the designing work. It is very difficult to design the golf club head so that the golf club head has superior restitution characteristics and a high strength at every portion of the face thereof.

As described above, according to the impedance matching theory, it is effective to mount a thin soft metal plate on the face part of the golf club head and form a soft portion widely thereon to improve the restitution characteristic thereof. But if the metal plate is soft, the golf club head has a problem in its strength. Thus to allow the golf club head to have a sufficient strength, the control of the thickness of the face part is a very important factor.

SUMMARY OF THE INVENTION

The present invention has been made in view of the above-described problems. Therefore it is an object of the present invention to efficiently design a golf club head

having superior restitution characteristic and a sufficient strength by utilizing a computer.

To solve the above-described problems, there is provided a method of designing a golf club head by using a computer, including the steps of using a club head model and a ball model both of which are composed of a plurality of divided finite elements; executing a simulation of impacting the club head model against the ball model at a reference hitting position set in a sweet area of a face part of the club head model and a plurality of comparison hitting positions set outside the sweet area; computing a stress generated in each of the finite elements by an analysis based on a finite element method, when the club head model impacts the ball model at the reference hitting position and the comparison hitting positions; and controlling a thickness distribution of each of the finite elements, based on a difference in a value of a stress generated at the reference hitting position and a value of a stress generated at each of the comparison hitting positions; and approximating a value of the stress generated when the ball model is hit outside the sweet area to a value of the stress generated when the ball model is hit inside the sweet area.

Thereby the stress generated at the reference hitting position and the stresses generated at the comparison hitting positions are made uniform.

More specifically, as shown in Fig. 11A, less than 80% of the area of the face is set as the sweet area in which the reference hitting position A is set. The portion of the face on the periphery of the reference hitting position A is divided into four regions S1 trough S4. The ratio of the area of the total of the four regions S1 trough S4 to the area of the face is set not less than 50% nor more than 200%. Comparison hitting positions B through E are set in the regions S1 trough S4 respectively or at a position on the boundary between the adjacent regions respectively or at a position a little to the sweet area from the regions S1 trough S4 respectively. The thickness control of the club head model is executed in each of the four regions S1 trough S4. For example, as shown in Fig. 11B, the thickness distribution control of elements I, II, III, … of the region S1 corresponding to the comparison hitting position B is executed.

To control the thickness distribution of the club head, the simulation of impacting the club head model against the ball model is executed in the computer by setting the thickness distribution of the golf club head as the variable; comparing the stress generated when the ball model is hit at the reference hitting position set inside the sweet area of the face with the stresses generated when the ball model is hit at the comparison hitting positions set outside the sweet area; and as the objective function, the stresses generated at

the comparison hitting positions set outside the sweet area are approximated to the stress generated at the reference hitting position set inside the sweet area. Therefore the method of the present invention is capable of enhancing the restitution performance of the golf club head when the golf ball is hit with the golf club head at positions outside the sweet area. Further it is possible not to thicken a portion of the face part to which strength should not be given but thicken a portion of the face part to which strength should be given. Thus the golf club head can be so designed that the face part has the thick portion and the thin portion in a favorable balance.

The golf club-designing method of the present invention is carried out based on the stress value computed by an analysis based on a finite element method. Thus it is very easy to design the wood head of the golf club without performing steps of making actual objects on an experimental basis or measuring the stress value. Further because the computer is used, the configuration and material of the golf club head can be changed by merely altering data. Thus it is easy to design the face part of the golf club head having various patterns in an imaginary space by using the computer.

The method of the present invention can be preferably used to design the wood club head.

That is, the club head model consists of a wood club

head model. The control of the thickness distribution of each of the finite elements is executed by controlling a thickness of a metal plate composing the face part of the wood club head model. The stress generated at each of the comparison hitting positions is compared with the stress generated at the reference hitting position. If the stresses generated at the comparison hitting positions are larger than the stress generated at the reference hitting position, portions of the metal plate disposed at the comparison hitting positions are thickened, whereas if the stresses generated at the comparison hitting positions are smaller than the stress generated at the reference hitting position, portions of the metal plate disposed at the comparison hitting positions are thinned, whereby the stresses generated at the comparison hitting positions are approximated to the stress generated at the reference hitting position.

As described above, it is possible to enhance the restitution performance of the golf club head by thinning the metal plate composing the face so that the natural frequency of the face part is approximated to that of the golf ball. Thus a portion of the face part generating a large stress, namely, a portion of the face part having high restitution performance is capable of obtaining restitution performance equivalent to that inside the sweet area by thickening a portion of the metal plate corresponding to the portion of the

face part generating the large stress. On the other hand, a portion of the face part generating a small stress, namely, a portion of the face part having low restitution performance is capable of obtaining restitution performance equivalent to that inside the sweet area by thinning a portion of the metal plate corresponding to the portion of the face part generating the small stress.

As described above, the restitution performance of the portion of the face part outside the sweet area is approximated to the restitution performance of the portion of the face part inside the sweet area. Further strength is given to the portion of the face part outside the sweet area.

A Mises' stress generated in each of the elements when the ball model is hit with the club head model is computed from a main stress value at an integration point of each of the elements; and a maximum value of the Mises' stress at each of the hitting positions is computed from a change of a time series of the found Mises' stress.

A part of the face part disposed at the comparison hitting position generating a smaller maximum value of the Mises' stress than a maximum value of the Mises' stress at the reference hitting position is thinned, whereas a portion of the face part disposed at the comparison hitting position generating a larger maximum value of the Mises' stress than the maximum value of the Mises' stress at the reference

hitting position is thickened.

The Mises' stress can be computed by the analysis based on the finite element method (FEM). One value of the Mises' stress is obtained for one element. Thus the Mises' stress is optimum for determining whether the material of the face part is destroyed. The Mises' stress generated in each element when the ball model is hit at the reference hitting position is computed. The Mises' stress generated in each element when the ball model is hit at the comparison hitting positions is also computed to compare the maximum value of the Mises' stress generated at the reference hitting position and the maximum value of the Mises' stresses generated at the comparison hitting positions with each other.

When the golf ball is hit, the maximum value of the Mises' stress is generated in an element present in the vicinity of the hitting position on the face. Therefore to make the stresses generated at the reference hitting position and the comparison hitting positions uniform, it is preferable to thicken the portion of the face part corresponding to the comparison hitting position showing a larger maximum Mises' stress value than the reference hitting position and the region disposed a little to the center of the face from the comparison hitting position. It is also preferable to thin the portion of the face part corresponding to the comparison hitting position showing a smaller maximum Mises' stress value

than the reference hitting position and the region disposed a little to the center of the face from the comparison hitting position.

The ball model is hit with the club head model at an initial speed of 40m/second, a maximum value of the Mises' stress generated at the reference hitting position and a maximum value of the Mises' stress generated at the comparison hitting positions is computed.

A thickness of the element disposed at the comparison hitting position is altered so that a difference between the maximum value of the Mises' stress generated at the reference hitting position and the maximum value of the Mises' stress generated at the comparison hitting positions is not more than 8 kgf/mm^2; and a simulation of impacting the club head model against the ball model is repeatedly executed to decide the thickness distribution.

The sweet area is widened by approximating the maximum value of the Mises' stress generated at the comparison hitting position to the maximum value of the Mises' stress generated at the reference hitting position. Therefore the simulation is repeatedly executed to make the difference between the maximum value of the Mises' stress at the reference hitting position and the maximum value of the Mises' stress at the comparison hitting position not more than 8 kgf/mm^2, favorably not more than 5 kgf/mm^2, more favorably not more than 1 kgf/mm^2.

The initial speed of 40m/s is generated when an ordinary golfer hits a golf ball with a golf club having the wood head mounted thereon. When the difference between the maximum value of the Mises' stress at the reference hitting position and that at the comparison hitting position is described as above, the strength of the face part can be held sufficiently when the golf ball is hit at other head speeds. It is possible to obtain an ideal golf club head by controlling the thickness distribution in repeated simulation of impacting the club head model against the ball model.

The reference hitting position is located inside a sweet area of the face part, and the comparison hitting position is formed at not less than three points outside the sweet area; and the reference hitting position is located in a region surrounded with straight lines connecting the comparison hitting positions.

It is preferable that the comparison hitting position is formed at not less than three positions nor more than the number of elements composing the face. As the number of the comparison hitting positions becomes more, it is possible to design the golf club head with higher precision but the period of time required to perform computations increases. If the comparison hitting positions are close to each other, almost equal stress values are generated by computations. Thus it is preferable to form the comparison hitting positions at

symmetrical positions with respect to the reference hitting position.

The center of the face is the geometrically central position of the face. It is preferable to set the comparison hitting position to the range located at 0.25L to 0.75L from the reference hitting position.

It is preferable that the comparison hitting position is formed at two points, with one point disposed upward from the reference hitting position and the other point disposed downward therefrom, and at two points with one point disposed at a left-hand side of the reference hitting position and the other point disposed at a right-hand side thereof.

The hitting position is formed at five points including the center of the plane of the face part, the two points disposed upward and downward from the center of the plane of the face part, and the two points disposed at the left-hand and right-hand of the center of the plane of the face part. The center of the plane of the face part is disposed in a rectangle formed by connecting the other four points. The thickness of the face part can be efficiently controlled by forming the comparison hitting positions not at a specific region on the plane of the face part but symmetrically with respect to the center of the plane of the face part.

The absolute value of the thickness of the face part can be determined by the absolute value of the Mises' stress.

Based on the absolute value of the Mises' stress and the properties of the material for the face part, the failure characteristics of the material can be grasped. Thereby the thickness distribution can be controlled and in addition, the thickness of each portion of the face part can be determined.

The designing method of the present invention can be suitably applied to the wood head having various configurations such as the wood head having a hollow portion. The designing method of the present invention is effective for designing the head of a driver and fairway wood clubs #1 through #9.

The designing method of the present invention which is carried out by utilizing a computer is also applicable to designing of an iron head in approximating the stress generated outside the sweet area to that generated inside the sweet area.

The designing method of the present invention is capable of forming the face part of the head having various configurations, for example, a flat surface or/and a curved surface by forming models in the computer. The face part can be made of metals such as titanium and alloys of metals. The material of the face can be altered partly. It is only necessary to input values indicating the properties of a material for a portion of the model to be altered.

The golf ball model can be made of materials that have

been hitherto used. Thus rubbers, polymer compositions using synthetic resin, and the like can be used to compose the golf ball model.

The head model can be composed of shell elements or solid elements. As the number of elements of the head model increases, computations can be performed with higher accuracy. In consideration of design efficiency, namely, in consideration of the performance of the present-day computer, the number of shell elements is preferably 5000 to 8000, and the number of solid elements is preferably 20000 to 30000. As the performance of the computer is improved, the period of time required to perform computations becomes shorter. Thus the head model can be composed of more elements in the future. The deformed configuration of the head at a hitting time can be displayed from the coordinate value of the nodal point of each element. Thereby The deformed configuration of the head at a hitting time can be evaluated, which is effective for designing the head.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a flowchart showing the method, of the present invention, of designing a wood head of a golf club.

Fig. 2A is a side view showing a head model.

Fig. 2B is a front view showing the head model.

Fig. 2C shows an initially set thickness distribution of

a face part of the head model.

Fig. 3 is a schematic view showing a golf ball model.

Figs. 4A, 4B, and 4C are explanatory views showing a situation in which the head model impacts against the golf ball model.

Fig. 5 is a graph showing a change of a stress, with the passage of time, generated in a certain element when the head model impacts against the golf ball model.

Fig. 6 shows hitting positions on the face of the head model.

Fig. 7 shows a change of maximum values of Mises' stresses with the passage of time generated at different hitting positions on the face part having an initially set thickness distribution.

Fig. 8 shows the thickness distribution of the face part having its thickness controlled based on results of an analysis.

Fig. 9 shows a change of maximum values of Mises' stresses with the passage of time generated at different hitting positions on the face part having its thickness distribution altered based on the results of the analysis.

Figs. 10A and 10B are graphs showing the coefficient of restitution of the face part having the initially set thickness distribution in comparison with the coefficient of restitution of the face part having its thickness distribution

altered based on the results of the analysis.

Fig. 11A is a schematic view showing how a reference hitting position and comparison hitting positions are set.

Fig. 11B is a schematic view showing the relationship between a hitting position and an element whose thickness is controlled.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The embodiments of the present invention will be described below with reference to drawings.

Fig. 1 is a flowchart showing the method of the present invention of designing a wood head of a golf club. The method will be described below based on the flowchart.

At step #1, a wood head model of a golf club and a golf ball model are formed in a computer; the models are divided into finite elements respectively; and data of the properties such as the thickness of a material for the face of the wood head model is inputted to the computer.

At step #2, supposing that a golf ball is hit with a golf club head, a simulation of impacting the wood club head model against the golf ball model at positions inside the sweet area of the face part of the wood club head model, namely, at a reference hitting position located at the geometrical center of the face and a plurality of comparison hitting positions located outside the sweet area.

At step #3, computations are performed by an analysis based on the finite element method (FEM) to obtain a stress generated in each element of the face part of the club head model as a result of the hitting at the reference hitting position and the comparison hitting positions.

At step #4, the difference between the stress generated at the reference hitting position and the stress generated at the comparison hitting position is evaluated.

At step #5, the thickness distribution of the face part of the club head model is controlled to approximate the stress generated as a result of the hitting outside the sweet area of the face to the stress generated as a result of the hitting inside the sweet area.

At step #6, if the difference between the stress generated at the reference hitting position and the stress generated at the comparison hitting position falls in the allowable range, the designing operation of the wood golf club head is finished, and wood golf club heads are made on an experimental basis and evaluated.

On the other hand, if the difference between the stress generated at the reference hitting position and the stress generated at the comparison hitting position is out of the allowable range, a simulation is executed again by changing the thickness distribution of the element in dependence on the value of the stress. Until the difference between the stress

generated at the reference hitting position and the stress generated at the comparison hitting position falls in the allowable range, the thickness control and the simulation of impacting the club head model against the golf ball model at the reference hitting position and the comparison hitting positions are repeatedly executed.

The designing method will be described in detail below.

Initially, the wood head model of the golf club and the golf ball model are formed by using the computer, and an initial condition is set.

Figs. 2A and 2B show the club head model of the wood head (hereinafter referred to as merely club head model) 10 used in the simulation. The club head model 10 is hollow and has a volume of 300cc and a weight of 188.0g. The club head model 10 is divided into 7394 elements 11 to obtain a large number of nodal points 12. The average length of one side of each finite element is about 2.5mm. The entire club head model 10 is composed of an elastic material divided into shell elements each having four nodal points. The thickness of each element 11 is altered at a plurality of portions of the club head model so that it has a configuration similar to that of an actual wood golf club head. The club head model 10 may be analyzed by using a solid model.

A face part 13 of the club head model 10 is almost elliptic plate-shaped and made of titanium, which is inputted

to the computer as the property of the face part 13. A face 13a is divided into 965 elements 11.

As shown in Fig. 2C, regarding the initial setting of the thickness of the face part 13, a central portion 13A of the approximately elliptic face part 13 is set to 2.7mm, and a peripheral portion 13B on the periphery of the central portion 13A is set to 2.0mm. That is, the initial thickness of the face part 13 is equal to the value of the thickness of XXIO W#1 commercially available.

As shown in Fig. 3, a golf ball model (golf ball model may be hereinafter referred to as merely ball model) 20 used in the simulation is entirely made of an elastic material divided into solid elements each having eight nodal points. The modulus of elasticity of the ball model 20 is adjusted so that the static compression characteristic thereof is similar to that of a "HI-BRID everio" (manufactured by Sumitomo Rubber Industries Inc.). The dimension and weight of the ball model 20 are also adjusted to be similar to those of the "HI-BRID everio". The ball model 20 is divided into 11800 elements 21 to obtain a large number of nodal points 22. The length of one side of each finite element is 0.2mm to 2mm. As the property of the material for the ball model 20, the modulus of elasticity and the Poisson's ratio are inputted to the computer.

By using the club head model 10 and the ball model 20,

as shown in Figs. 4A, 4B, and 4C, simulations are conducted, supposing that the golf club head hits the golf ball.

More specifically, after the ball model 20 is disposed at a position near a portion of the club head model 10 at which the club head model 10 hits the ball model 20, the club head model 10 hits the ball model 20 at an initial speed of the club head model 10 is set to 40m/second. A stress generated in each element of the face part 13 of the club head model 10 when the club head model 10 impacts the golf ball model 20 is analyzed by using the finite element method (FEM).

Fig. 5 shows a stress-generated situation of a certain element at the time when the ball model 20 is hit. As shown in Fig. 5, the value of the generated stress changes with the passage of time (analysis step). The stress becomes maximum at about the middle point of the time period of contact between the club head model 10 and the ball model 20.

The period of time from the time of the collision therebetween until the time when the ball model 20 separates completely from the club head model 10 is computed. The coefficient of the dynamic friction and that of the static friction at the time of the contact therebetween are set to both 0.3.

As shown in Fig. 6, regarding the hitting positions in this embodiment, the reference hitting position is set to a central point A located inside the sweet area and at the

geometrical center of the face 13a. The comparison hitting position includes four points of B, C, D, and E. More specifically, the point B is situated at the tow side and 20mm apart from the central position. The point C is situated at the heel side and 20mm apart from the central position. The point D is situated 10mm upward from the central position. The point E is situated 10mm downward from the central position. The positions of the four points of B, C, D, and E are so set that the point A is present inside a rectangle formed by connecting the four points of B, C, D, and E.

In the embodiment, the number of the comparison hitting positions is only four points of B, C, D, and E. Thus when the thickness control range is disposed at the peripheral edge of the face 13a, the comparison hitting positions are set a little to the center of the face 13a where a higher stress is generated than the thickness control range (peripheral edge). It is most favorable to set the comparison hitting position and the thickness control position at the same position. However, it is difficult to set the comparison hitting positions at all positions outside the sweet area of the face 13a. Therefore as described above, the thickness control is made at positions outward from the comparison hitting positions.

Of the comparison hitting positions B through E, a thin portion is formed on an edge portion of the face 13a disposed

on the periphery of one or more comparison hitting positions B through E at which a low stress is generated.

The stress generated in each element of the face part of the club head model when the club head model impacts the golf ball model at the reference hitting position and the comparison hitting positions is computed (analyzed) by using the finite element method (FEM).

More specifically, from a main stress value at an integration point of each element of the face part and by using an equation 1 shown below, computations are performed to find a Mises' stress generated in each element of the face part when the ball model is hit at each hitting position. In the equation 1, σe is the Mises' stress; $\sigma 1$ is a maximum main stress; $\sigma 2$ is an intermediate main stress; and $\sigma 3$ is a minimum main stress.

Equation 1

$$\sigma_e=1/2((\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2)^{1/2}$$

A maximum value of the Mises' stress is computed from the time series change of the found Mises' stress in each element. The shell element is used in the embodiment. The number of integration points in the thickness direction is set to two. The maximum value of the Mises' stress at all integration points is computed. By carrying out this method, the maximum value of the Mises' stress generated in the face part is computed, when the club head model impacts the golf

ball model at each of the five hitting positions.

Fig. 7 shows the change of the maximum value of the Mises' stress with the passage of time at each hitting position of the head model 10 having an initially set thickness distribution. Comparison is made between the maximum value of the Mises' stress generated at the reference hitting position and maximum value of the Mises' stress generated at the comparison hitting positions.

As shown in Fig. 7, in the initial thickness distribution, the difference between the maximum value of the Mises' stress generated when the ball model is hit at the comparison hitting position E located 10mm downward from the central position of the face 13a and the maximum value of the Mises' stress generated when the ball model is hit at the reference hitting position A located at the geometrical center of the face 13a is largest, namely, about 14 kgf/mm^2.

In this embodiment, the Mises' stress generated when the ball model is hit at the reference hitting position A is set as the reference allowable stress.

The difference between the maximum value of the Mises' stress generated at the comparison hitting position E and the maximum value of the Mises' stress generated at the reference hitting position A exceeds 8 kgf/mm^2 which is the allowable range. Therefore the thickness distribution of the face part is altered from the initially set value.

That is, thickness distribution is controlled as follows: When the maximum value of the Mises' stress at any of the comparison hitting positions B through E is larger than the maximum value of the Mises' stress at the reference hitting position A, the comparison hitting position and the peripheral portion thereof is thickened and particularly the region disposed a little to the center of the face 13a from the comparison hitting position is thickened. On the other hand, when the maximum value of the Mises' stress at any of the comparison hitting positions B through E is smaller than the maximum value of the Mises' stress at the reference hitting position A, the thickness of the comparison hitting position and that of the peripheral portion are thinned and particularly the region disposed a little to the peripheral side of the face from the comparison hitting position is thinned.

In this embodiment, as shown in Fig. 8, the thickness of the central portion 13A of the approximately elliptic face part 13 remains 2.7mm which is initially set, and an upper portion 13Ba upward from the peripheral portion 13B disposed on the periphery of the central portion 13A remains 2.0mm which is initially set. The thickness of a lower portion 13Bb downward from the peripheral portion 13B is altered to 1.6mm. By using the head model whose face part 13' has been changed in its thickness distribution, the simulation is executed

again in the above-described procedure.

Fig. 9 shows the change of the maximum value of the Mises' stress with the passage of time at each hitting position of the head model 10 having the face part 13' changed in its thickness distribution. Comparing the maximum values of the Mises' stress generated at the reference hitting position A and each of the comparison hitting positions B through E, as shown in Fig. 9, the difference between the maximum value of the Mises' stress generated at the comparison hitting position C situated at the heel side and 20mm apart from the central position and the maximum value of the Mises' stress generated at the reference hitting position A located at the geometrical center of the face 13a is larger than the difference between the maximum value of the Mises' stress generated at the reference hitting position A and each of the maximum value of the Mises' stress generated at the comparison hitting positions B, D, and E, but not more than 8 kgf/mm^2. The maximum value of the Mises' stress does not exceed the allowable stress described previously.

The difference between the maximum value of the Mises' stress generated at the comparison hitting position and the maximum value of the Mises' stress generated at the reference hitting position is not more than 8 kgf/mm^2. The maximum Mises' stress is less than the set allowable stress. Therefore stresses generated when the ball model is hit at different

positions of the face part are approximated to the stress generated at the reference hitting position. That is, an intended thickness distribution can be achieved. Thus the thickness distribution of the face part is decided finally. The obtained result can be utilized for steps of making the golf club head on an experimental basis.

To examine the restitution characteristic of the wood head formed by using the designing method of the present invention, a simulation of impacting the club head model against the ball model was conducted by using the head model having the thickness of its face part altered based on the results of the above-described simulation and the head model whose face part has the initially set thickness distribution. The coefficient of restitution of a golf ball was computed in the simulation.

- Computation of restitution coefficient by analysis

Mass was distributed to nodal points constituting one element. Each nodal point was replaced with a material point. Regarding the speed of the nodal point as the speed of the material point, the total amount of each speed of nodal point is divided by the number of nodal point to obtain the speed of the entirety. Thereby the speed of the hit golf ball and that of the head can be computed. The restitution coefficient of the golf ball is computed from the speed and weight of the golf ball and the head.

Figs. 10A and 10B show the restitution coefficients of the club head model at different hitting positions. As shown in Figs. 10A and 10B, at each hitting position, the head model having the thickness of its face part altered based on the above-described procedure has higher restitution performance than the head model whose face part has the initially set thickness distribution.

In this embodiment, as an analysis software, an LS-DYNA: manufactured by LSTC Inc.) is used to execute the simulation. In addition, an ABAQUS Explicit (manufactured by HKS Inc.) and a PAM-CRASH (manufactured by ESI Inc.) may be used. As the finite element model, a beam element, a shell element, a solid element, and a combination of these elements can be used. Analysis conditions can be altered appropriately.

The absolute value of the thickness of the face part can be determined by the absolute value of the Mises' stress. The hitting position can be altered appropriately, provided that a plurality of hitting positions is set on the face part. The configuration and material for the face part of the wood head and the golf ball can be set appropriately.

As apparent from the foregoing description, according to the present invention, by using the club head model and particularly the wood head model and the ball model both of which are composed of a plurality of divided finite elements, stresses generated in the face part when the ball model is hit

with the ball model at a position inside the sweet area of the club head model and at positions outside the sweet area are computed. Based on values of the stresses obtained by the computation, the thickness of the club head is thinned or thickened to thereby approximate the value of the stress generated outside the sweet area to the value of the stress generated inside the sweet area. Thereby it is possible to make the thickness of the face part optimum in its restitution performance and strength. That is, the method of the present invention is capable of designing the club head efficiently.

That is, according to the method, the area of a thin soft portion is widened in the face part to enhance the restitution performance of the face part. Further the thickness of the face part is so set as to obtain a high strength. That is, the method is capable of efficiently designing the club head and particularly the wood head having high strength and restitution performance.

Computations are performed in an imaginary space by using a computer. Thus it is unnecessary to measure stress values. Further because the computer is used, the configuration and material of the golf club head can be changed by merely altering data. Therefore it is easy to design the face part of the club head having various patterns. In addition, the method of the present invention reduces the number of trial products of the club head, the expense and

time required to make the trial products, and the period of time required to design the club head.